DOCUMENT RESUME

ED 321 440 EC 231 560

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TITLE A Computer Approach to Teaching English Syntax to Deaf Students.
INSTITUTION American Institutes for Research in the Behavioral Sciences, Palo Alto, Calif.
SPONS AGENCY Special Education Programs (ED/OSERS), Washington, DC.
PUB DATE Apr 90
NOTE 26p.; Paper presented at the Annual Meeting of the American Educational Research Association (Boston, MA, April 16-20, 1990).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Descriptive (141) -- Reports - Evaluative/Feasibility (142)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Computer Assisted Instruction; Computer Graphics; *Deafness; Educational Games; English Instruction; Error Correction; Feedback; *Microcomputers; Secondary Education; *Syntax; *Teaching Methods; *Visual Learning

ABSTRACT

A computer-based method of communicating syntactic knowledge to deaf students was designed, building on the visual orientation of deaf students and employing such American Sign Language techniques as visualization and directionality. The computer-based instructional treatments were presented as an educational game called the "Yes-No Game," with visual effects using the high resolution graphics capability of the Macintosh computer. As learners created sentence-pictures and built yes-no questions, animated graphics pictured the transformation of sentences to questions. Textual and graphic corrective feedback were displayed on the computer screen to respond specifically to each error that students made in building English questions. Seventeen treatment subjects in grades 8-11, compared with 15 control subjects, showed significant gains in recognition of correct grammatical structures but showed only marginal improvement in actual sentence production. With accompanying pictures to aid comprehension, and with multiple opportunities to practice and to receive immediate visual feedback, the experiment demonstrated that an instructional foundation and methodology can be provided that will help deaf students overcome their difficulties in building yes-no questions in English. (JDD)

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A Computer Approach to Teaching English Syntax to Deaf Students

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Paper Presented
at the Annual Meeting of the
American Educational Research Association
Boston
April, 1990

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This research was supported by a grant to the American Institutes of Research from the Office of Special Education Programs, U. S. Department of Education.

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Abstract

The formidable difficulties that deaf students experience in learning English are reflected in the large number of functionally illiterate deaf adults. To date, instructional methods have not effectively developed the ability of the Deaf to read and write English sufficiently. As a result, the majority of deaf adults remain undereducated, underemployed, and limited in their ability to participate fully in our society. Building on the visual orientation of the Deaf, and employing such American Sign Language (ASL) techniques as visualization and directionality, we designed a computer-based method of communicating syntactic knowledge to deaf students.

Yes-No II, the subject of this paper, is the second study in a series of research interventions using computer-based instructional treatments presented as educational games. To achieve the visual effects essential to our instructional approach, we used the high resolution graphics capability of the Macintosh; textual and graphic corrective feedback, displayed on the computer screen, respond specifically to each error that students make in building English questions, and enable them to correct their misunderstandings. With accompanying pictures to aid comprehension, and with multiple opportunities to practice and to receive immediate visual feedback, the experiment demonstrated that an instructional foundation and methodology can be provided that will help deaf students overcome their difficulties in building yes-no questions in English.

To assess treatment effects, reliable tests were constructed to measure the efficiency of the *Yes-No* computer-based materials in teaching specific English syntax skills. These tests consisted of two parts: Part I, in a multiple choice format, measured the students' recognition of correct grammatical structures, and Part II elicited actual sentence production. Developed in several forms, the tests were administered in a pre-post test evaluation. Especially Part I of these tests showed rapid improvement in areas of syntax in which progress with conventional materials in the classroom is at best extremely slow.

Introduction

An effective, comprehensive program of instruction for deaf students in basic English reading and writing skills has yet to be developed. Only 10% of the best 18 year-olds read at or above the eighth grade level, and the average deaf adult reaches only a fourth grade reading level (Quigley, 1984). As a result, large numbers of deaf adults remain functionally illiterate.

Although the Deaf have been disadvantaged by their handicap, developments in research and practice suggest a promising future. Recent theory and research in linguistics have extended to studies of language and communication of the Deaf. The pioneering work of William Stokoe (1960) followed by Bellugi (1972), Newport (1977), Siple (1978), and Lane and Grojean (1980), indicated that American Sign Language (ASL) was indeed a "natural" language. Where English is a natural aural-oral[1] language, ASL is a natural visual-gestural[2] language that has evolved to meet the specific communication needs of the Deaf. Using highly visual information processing and storage techniques, the Deaf acquire linguistic structures with facility in ASL; yet, they experience great difficulty learning comparable structures in aural-oral languages. This paper reports on the efectiveness of an intervention which used techniques of computer-based instruction that were grounded in a methodology of visual information processing to facilitate language acquisition by the Deaf.

Theoretical Framework

In order to design an effective instructional program, we needed to understand why the Deaf have difficulty understanding English, particularly syntax. First, we turned to the research in cognitive psychology and psycholinguistics which demonstrated the many ways in which the Deaf rely on visual coding rather than auditory/speech coding (Conrad, 1973; Lichtenstein, 1983). This unique processing style, which may render traditional instruction inaccessible, suggests that presentations that are visually oriented might be especially effective. Pointed toward highly visual techniques, we realized that we could take advantage of the possibilities of visual presentations on the computer to help deaf students learn those aspects of English syntax with which they traditionally experience difficulty in English but comprehend with ease in ASL (Fogel, 1986 &1988). We found strong support for our endeavor to apply technological innovations to the problems of linguistic processing of deaf children in the well known document, Toward Equality: Education of the Deaf, (Commission, 1988).

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[1] Aural-oral indicates that language is received auditorally and transmitted through speech.
[2] Visual-gestural indicates that language is received visually and transmitted in space through signs and gestures.

With the availability of new computer technology for instruction, many of the obstacles to effective English syntax instruction for the Deaf may be removed. The potential of computers to build highly visually-oriented materials can capitalize upon the visual-gestural grammar inherent in ASL and expose deaf students to the rich English language environment that their hearing peers experience daily. Hearing children enter school with a fairly complete knowledge of the syntax and lexicon of the English language; they learn to map the written word onto what they know "sounds right." In contrast, deaf students who have never heard English are expected to replicate the lexicon and syntax; they must learn how to read and write an auditorally based language without access to the spoken word.

Microcomputer-based language programs, however, can offer a way to build upon the prior language-related, visual knowledge that the Deaf acquire in learning sign language. Even if the learners are not competent in sign language, we can assume a predisposition to rely on a visual modality in their communication. Most English instruction focuses on the linear sequencing of the language; it does not demonstrate linguistic relationships by movement in space. However, computer-assisted instruction (CAI) can add the ASL dimensions of position and motion in space to enhance English language learning; as a result, educational software can offer hearing-impaired students more rewarding opportunities for interactive language experience than they usually encounter. Utilizing visualization,[3] directionality,[4] and simultaneity of expression,[5] which the Deaf use so effectively in ASL communication, CAI can employ graphics, windows, and reverse video to highlight and emphasize instructional points and corrective feedback. Through CAI designed specifically for the hearing-impaired, students can be motivated to interact with an instructional environment in which the syntax, vocabulary, and figurative language are linguistically controlled and incrementally graduated in difficulty. English language acquisition and usage can proceed at the learner's own pace, but more rapidly than previously experienced by deaf students.

Drawing on successful language research on the education of deaf persons (e.g., Iran-Nejad, 1981), we applied a Direct Instruction approach (Becker & Engelman, 1977). Although the term "direct instruction" is associated with a small set of educational researchers, there is some

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[3] Visualization — focusing on sight (e.g., using computer graphics and video effects) as the primary mode of communication to convey syntactic information.

[4] Directionality — modulations (e.g., of verbs) to indicate such grammatical relationships as subjects, objects, and locations.

[5] Simultaneity of expression — the co-occurence of grammatical or lexical information (e.g., aspects of time, as regularity, duration, repetition, tense).

consensus among a wide range of instructional psychologists on a core set of design principles which are fundamental to direct instruction. The learner should:

- have the prerequisite knowledge to use the instruction and to learn additional skills
- be motivated
- be guided through models which make clear when and how to apply new knowledge
- have ample opportunities to demonstrate their mastery of models in a context that makes errors likely, if the learners have not understood the new content well
- be able to benefit from corrective feedback

To test the effectiveness of an instructional intervention to teach English syntax skills to the Deaf, we (1) used the computer's special graphic capability to present concepts linked to the visual-gestural knowledge base of the Deaf, and (2) grounded the instructional design in a Direct Instruction approach.

Preceding Work

This paper details one of a series of studies to determine whether highly visual techniques associated with ASL could be effectively used in computer-assisted English syntax instruction designed specifically for Deaf students. An introductory phase of the experiment, *Choosing AVMs* (Advanced Visual Markers), consisted of an inquiry to determine which of several visual markers signifying interrogation and negation would be considered most effective as syntax clues by different types of hearing-impaired populations. The results of that study indicated that students selected AVM icons closely related to their primary mode of communication — ASL, SEE II, or Aural-oral English — leading us to conclude that different visual clues may be more effective for hearing-impaired groups with different language backgrounds (Fogel, 1988).

The first experiment dealt with the effectiveness of computer-assisted remedial instruction for the Deaf in the formation of yes-no questions in English. The study dealt with questions involving BE as a main and auxiliary verb. The experiment utilized specifically produced CAI material for treatment and control groups in the form of computer games, specifically produced tests, and error analysis of materials produced by students in the test situation. The treatment material that was devised made use of ASL visualization techniques and simultaneity of expression — made possible by the use of the Macintosh computer.

This experiment, the *Yes-No Game I*, used a simple pre- post-test design and included, in addition to the CAI treatment, the use of a distinct Advanced Visual Marker (icon), and the students' reading comprehension scores as independent variables in the evaluation of the experiment. The results showed clearly that the CAI treatment contributed significantly to gains from pre- to post test; the use of the AVM icon, however, did not contribute significantly. Reading scores contributed significantly only in Part II of the test, the language production section that depends upon the comprehension of stimulus paragraphs. The game format and other design features utilized in the first study were retained in the research reported in this article.

Development of Treatment Materials

We tested learners of different grades (7-12) to determine (1) the structures with which secondary students experienced difficulty, and (2) the age at which they mastered those grammatical patterns. Using Quigley's Test of Syntactic Abilities (TSA) as a model, we developed a 100-item Diagnostic Test of Interrogative and Negative Patterns, which we administered to 72 students at a residential school for the Deaf. All test items used the multiple choice method. The first 70 items required the recognition of correct English grammaticality; the last 30 asked the student to identify a sentence which follows from, or is at least semantically compatible with, a situation briefly described in the item stem. By analyzing the frequency of mistakes on the Diagnostic Test, and considering the linguistic problems underlying these mistakes, linguists identified appropriate targets for syntax instruction and remediation. The target chosen for this study was the use of the auxiliaries DO, DOES, and DID. In addition, the distribution of error frequencies and types by grade levels helped to define the population that had sufficient prerequisite English syntactic knowledge to be able to benefit from the intervention, but who lacked the ability to correctly build the structure to be taught; the test analysis also aided us in constructing subsequent tests which were used to form matched treatment/control groups.

The teaching materials we developed took the form of a computer game, the *Yes-No Game*, which employed a variety of visualization techniques to maximize learning for the Deaf. The computer materials for each study included:

- Interactive instructions on how to use the Macintosh for the *Yes-No Game*

- Animated screens illustrating the transformation of a declarative sentence to a yes-no question
- Practice sessions in which the students:
    1. Create a sentence-picture
    2. Build a yes-no question
    3. Receive visual and written corrective feedback for each error
    4. Review earlier lessons and transformations if in need of remediation, or
    5. Progress to sentences of increasing length and difficulty

To enhance the visualization of the interactive Macintosh instructions, we incorporated VideoWorks, a computer program which simulates motion pictures. To help those students who were unfamiliar with the Macintosh and had experienced difficulty manipulating the mouse, a VideoWorks animated drawing of the moving, lifting, and repositioning of the mouse explained visually how to use the mouse.

To develop excellent graphically oriented material in a relatively short period of time, HyperCard had been utilized in a previous study involving the BE verb and icons as a visualization technique. The performance of *Yes-No II*, the study reported here, was improved by the use of MacApp, an object-oriented programming language that efficiently implements the standard features of most Macintosh applications. Because the AVM icons were not associated with pre-post-test gains in the previous study, they were omitted in the practice sections of this study. However, we incorporated an AVM icon in the initial transformation screens to indicate that a sentence had been transformed to a question; the AVM question icon floated across the question to replicate the ASL facial expression that is present as a linguistic marker during the signing of a yes-no question.

To guide learners through visual syntactic models, animated graphics picturing the transformation of sentences to questions preceded multiple practice opportunities for each syntactic structure taught. By visually depicting the transformation of a declarative sentence to a question, as shown in Figures 1 and 2, the students were provided with an alternative to relying exclusively on printed text for reading comprehension. For example, after a declarative sentence appears in the *Yes-No II Game* (The president of the bank **unlocks** the vault), the "s" in "unlocks" duplicates itself in the line above; "doe" appears and meets the "s" to form "does." Next, "unlock" in the

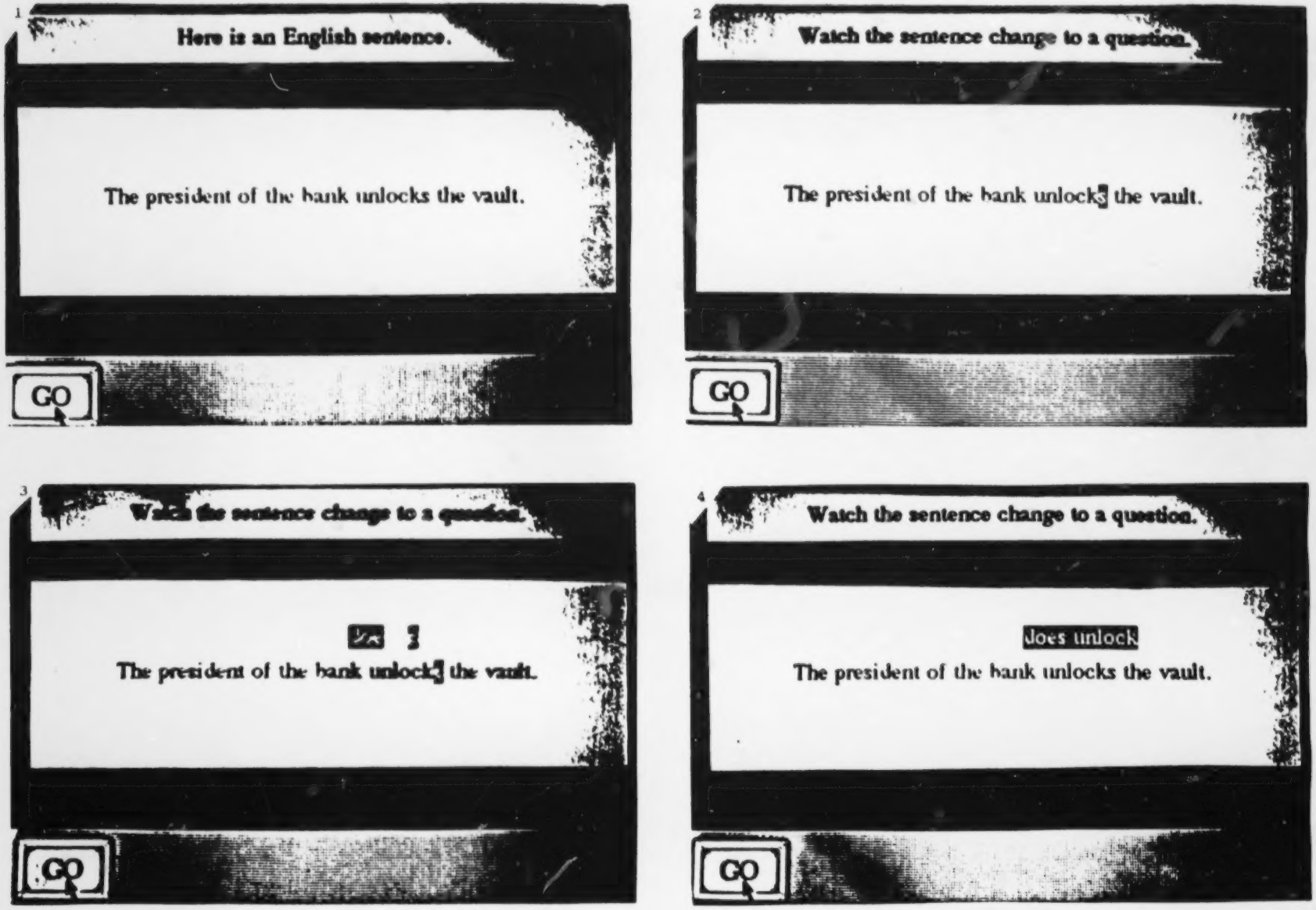

1
Here is an English sentence.
The president of the bank unlocks the vault.
GO
2
Watch the sentence change to a question.
The president of the bank unlocks the vault.
GO
3
Watch the sentence change to a question.
The president of the bank unlock the vault.
GO
4
Watch the sentence change to a question.
does unlock
The president of the bank unlocks the vault.
GO

Figure 1. Transformation of a Declarative Sentence to a Question — *Yes-No II*

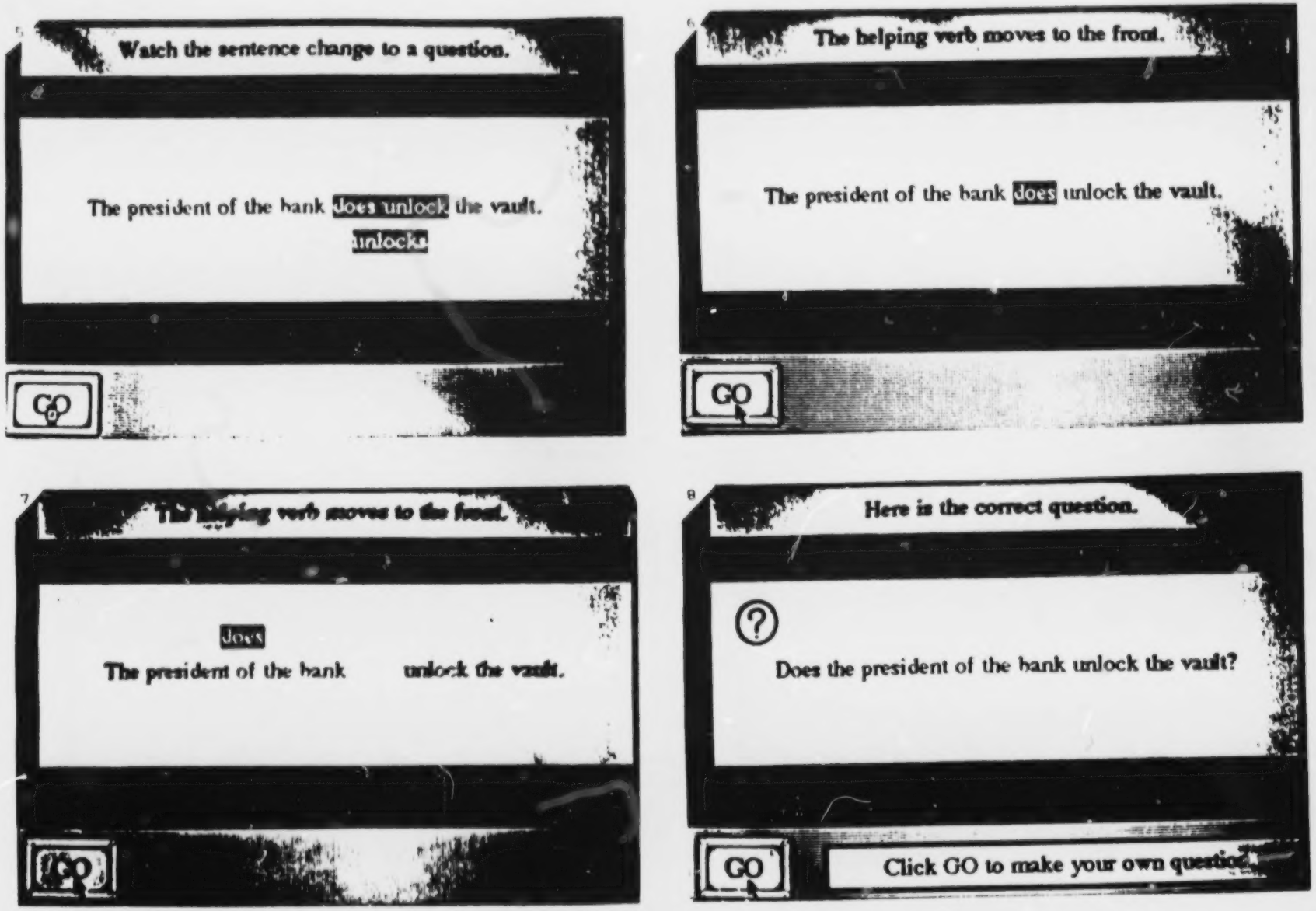
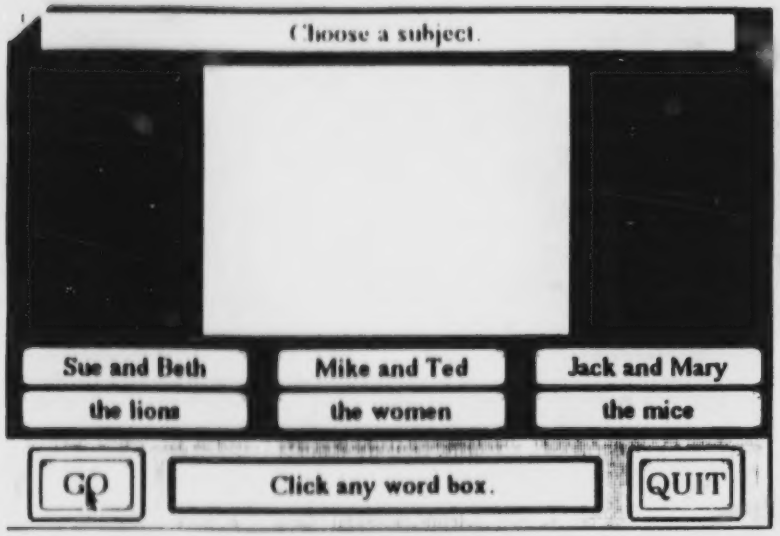

Watch the sentence change to a question.
The president of the bank does unlock the vault.
unlocks
GO
The helping verb moves to the front.
The president of the bank does unlock the vault.
GO
does
The president of the bank unlock the vault.
GO
Here is the correct question.
Does the president of the bank unlock the vault?
GO
Click GO to make your own question.

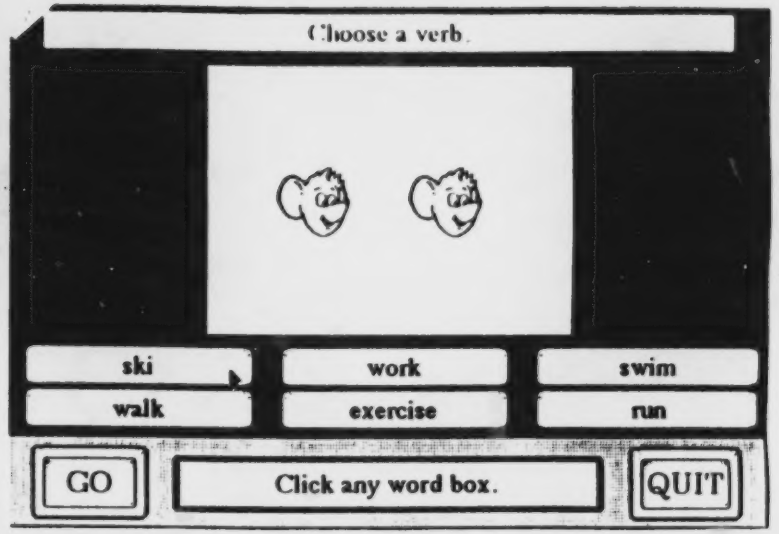
Figure 2. Transformation of a Declarative Sentence to a Question — *Yes-No II*

sentence duplicates itself in the line above; "does unlock" in the line above flashes alternately with "unlocks" in the sentence to visually state that both expressions are the same. Slowly, "does unlock" movesdown into the sentence to replace "unlocks," which moves down and dissolves. In the new sentence (The president of the bank **does unlock** the vault), "does" flashes and moves to the line above; "does" travels left to the beginning of the sentence, where it drops into place. The empty space which held the auxiliary verb closes, the "d" in "does" is capitalized, and a question mark replaces a period at the end of the sentence (Does the president of the bank unlock the vault?). Such visual representations of language structures and transformations are an integral part of both the instructional modeling and the immediate, corrective feedback in the *Yes-No II Game*.

To capitalize on ASL's visualization and simultaneity of expression, computer graphics and animation are incorporated to enhance comprehension, clarify meaning, and maximize the transfer of relevant knowledge. In addition, to engage and motivate the learners, we involve them as active participants in their instruction. First, students are provided with multiple opportunities to build their own — often humorous — sentences, which are automatically illustrated by the program. As shown in Figure 3, "Creating a Sentence-Picture," a student chooses the subject "mice" from among six possibilities (which are randomly selected from a file of 20 possible subjects), and the heads of two mice appear in the picture box above the word choices. Next, if the student chooses the verb "ski" from among six randomly displayed verbs, the picture changes to display the mice skiing. Similarly, direct objects and adverbials of time and place are selected; as each word is picked, a visual counterpart is added to the picture to represent the sentence as it is built by the student.

After the sentence is completed and its picture displayed, the "Building a Question" screen invites the student to create an appropriate yes-no question for the picture. Figure 4 displays a sample screen containing a picture and a matrix of possible words and phrases from which students build their own questions. Unlike most CAI, the *Yes-No Game* does not limit learners to making simple choices among a set of "right answers." Rather, students were tested to identify common misunderstandings and errors in yes-no syntactic patterns; distractors that could result in the students' manifesting these misunderstandings were incorporated in the program, and effective corrective feedback that responded to individual students' errors was provided. For example, for a picture of Leo driving a truck every day, the randomly presented items could include a period, a question mark, and the following words: Leo, do, does, did, drive, drives, drove, a truck, and every day.





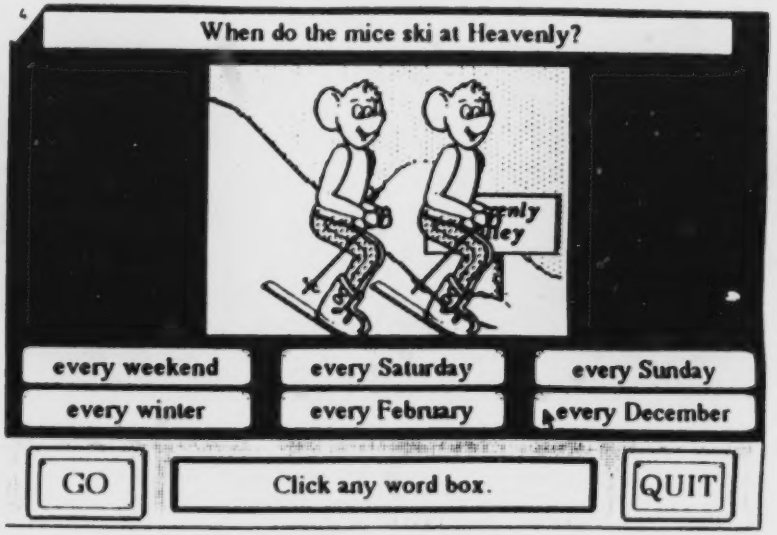


Figure 3. Creating a Sentence-Picture — *Yes-No II*

Multiple opportunities for initiating interactive practice are provided. Students have as many as 10 opportunities to build each question; for each attempt, learners benefit from detailed, corrective feedback for common errors (about 20 per structure). The feedback is designed to provide specific visual and written responses for each type of error. A first incorrect try results in a written and visual hint; a second incorrect attempt in the same error category provides more specific information, and the third supplies the correct answer with a textual and visual explanation. If the student cannot correct the mistake after several tries, the student's incorrect question is visually transformed to the correct syntactic pattern through animation. Figure 4 illustrates the use of brief, linguistically controlled messages that respond specifically to some of the likely misunderstandings that lead to students' common errors in yes-no questions: (1) omitted, incorrect, misplaced, or repeated auxiliary, (2) double marking the tense on both the auxiliary and main verb, and (3) incorrect word order. Of equal or greater importance is the visual feedback to incorrect questions that students build: the error is highlighted in the student's question while the correct possibilities are flashed slowly in the word matrix; a double tense marking is highlighted with underlining and an "X" over the incorrect suffix, and the correct place of the auxiliary in the question is indicated by a flashing arrow.

Provision to review structural modeling was built into the program for instances when the specific, corrective feedback was insufficient to correct misunderstandings; however, the immediate feedback proved so effective that none of the subjects ever triggered the more detailed modeling reviews. The success of the feedback can perhaps be attributed to its visualization — video "effects" such as flashing, highlighting, and reverse video, as well as such graphics as the pointing arrow to emphasize instructional points.

Subjects

To ensure the participation of a large number of high school subjects who had sufficient prerequisite English syntactic knowledge to benefit from the *Yes-No Game*, but who lacked the ability to form yes-no questions, we conducted the intervention at a residential school for the Deaf. After the principal and teachers screened out the learning disabled students because of their insufficient prerequisite syntactic knowledge, and the advanced students whose English language placement indicated that they had already mastered the treatment material, the Yes-No Screening/Pre-test was administered to 76 eighth, ninth, tenth, and eleventh grade students. The

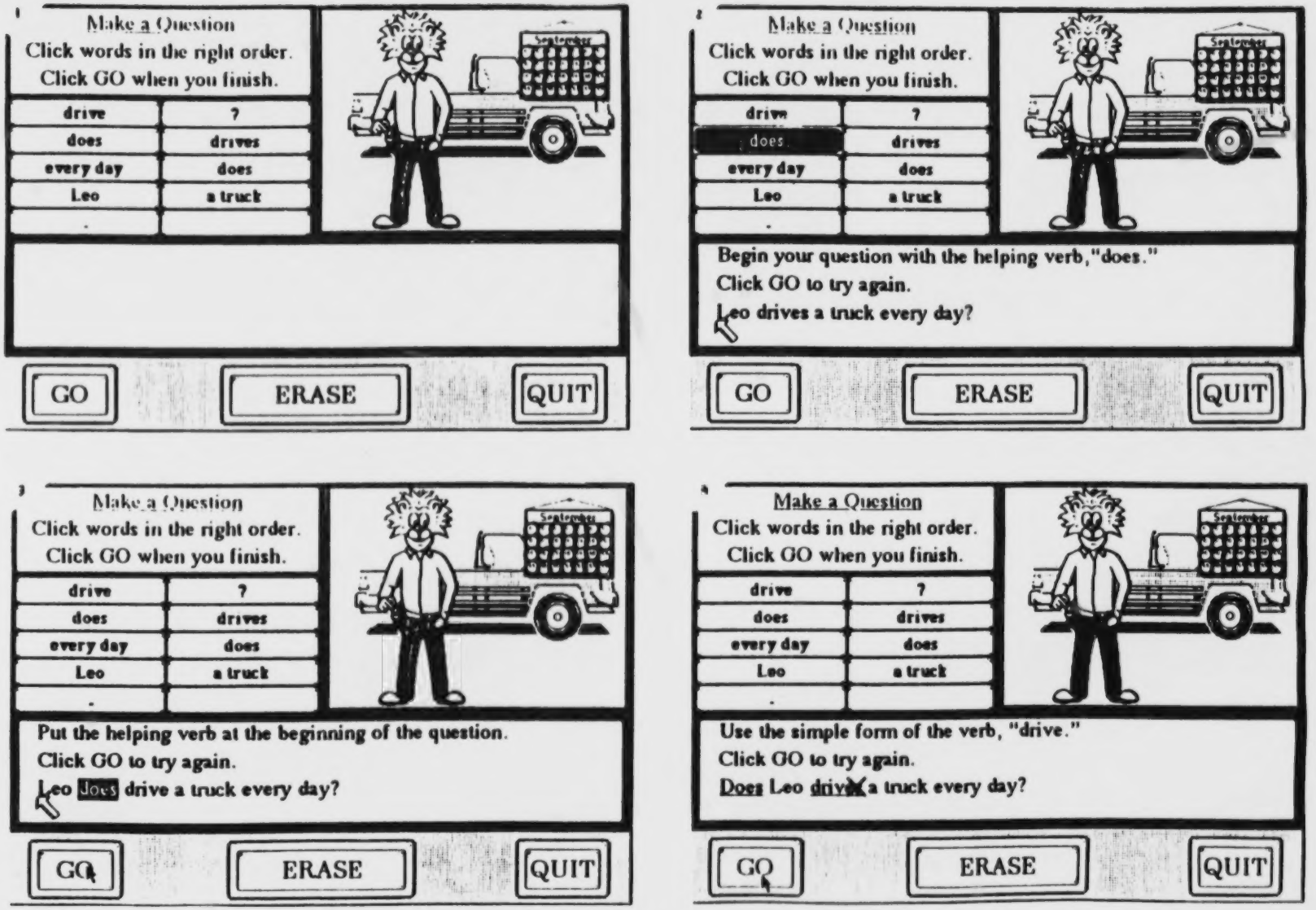


Figure 4. Building a Question — *Yes-No II*

test was composed of two parts: Part I, which consisted of 25 items modeled on Quigley's TSA multiple choice format, measured the students' recognition of correct grammatical yes-no question structures; Part II elicited actual yes-no question production in response to a short paragraph stimulus. Students who scored above 85% or below 25 % were eliminated from the pool of possible subjects because they had demonstrated that they did not need the yes-no intervention or did not possess sufficient knowledge of English to be able to benefit from the treatment material. The subjects for the intervention were selected and matched on two criteria: their recent SAT-HI reading scores, and their performance on the Yes-No Screening/Pre-test. For each pair, one subject was randomly assigned to the treatment group and the other to the control group; the process resulted in two groups of 18 students with comparable syntactical knowledge of written English. The subsequent loss of subjects during the research process resulted in an eventual sample which consisted of 17 treatment and 15 control subjects, ages 14 to 18.

Data Collection

The *Yes-No II* Study was a two phase intervention, which tested the null hypotheses: CAI designed to teach English syntax to deaf high school students would have no effect on their syntactic knowledge. Figure 5.1 shows the schematic diagram of the experimental design. One week prior to the first phase, Test 1 of a two-part pencil and paper test was administered to both the treatment and control groups. Part I of the test was modeled on the diagnostic sub-tests for question formation of Quigley's TSA; composed of 25 multiple choice items, it required the recognition of correct English grammaticality. Part II consisted of 10 open-ended items for which students were asked to write an appropriate question in response to a stimulus of one to three short sentences. A question that could be interpreted as having been logically and meaningfully stimulated by the short paragraph, and that did not contain syntactic errors for which the subjects had received instruction, was accepted as a correct response. Part II involved active sentence construction and was therefore a more difficult task for the students.

As shown in Figure 5.1, the treatment group (A) completed the three lessons in the CAI-Syntax program in two to three class periods (90 to 135 minutes). To minimize and possibly control the impact of a possible Hawthorne effect, the control group (B) used an alternate computer program in an unrelated subject area for the same period of time. For both the treatment and control groups, students proceeded through the computer programs individually; each learner controlled the pace. Within one day after completion of the first phase of the CAI intervention, Test 2 was administered to both groups. Two weeks after the administration of Test 2, Group A

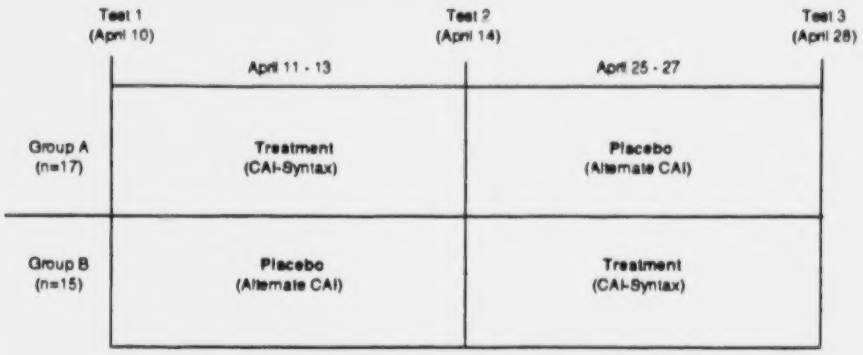


Figure 5.1 Schematic Diagram of the Experimental Design

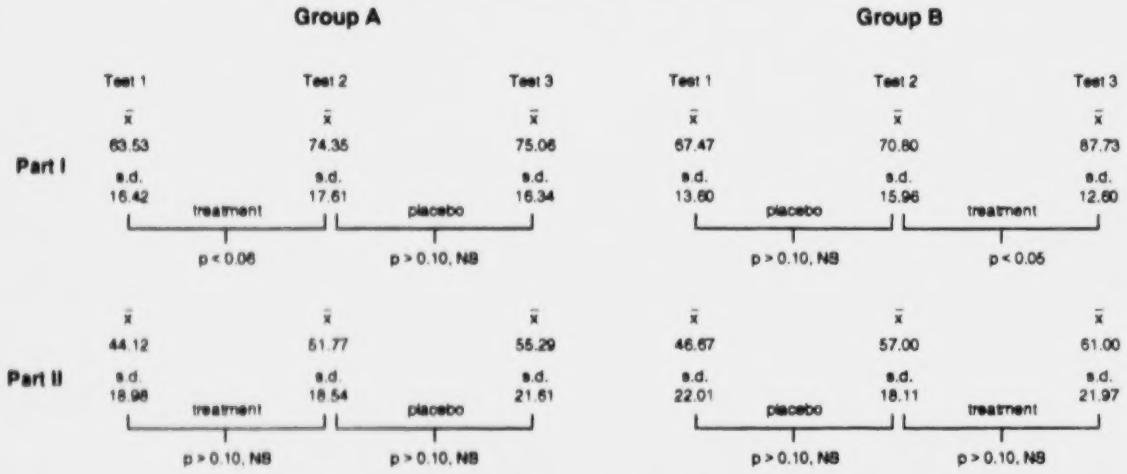


Figure 5.2 Comparison of Group Means of Test Scores (Significance levels determined by ANOVA "Least Significant Difference" test of paired contrasts)

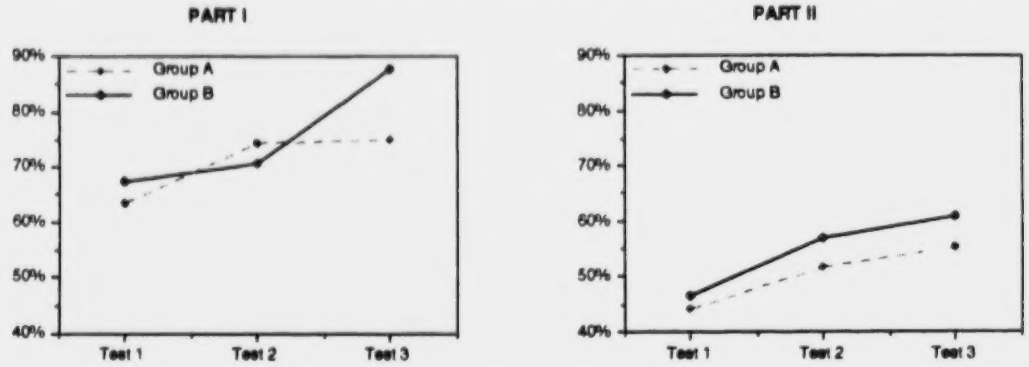


Figure 5.3 Effects of CAI Instruction and Alternate (Placebo) CAI

Figure 5. ***Yes-No II*** **Results**

used the alternate computer program, and Group B used the CAI-Syntax program. The next day, Test 3 was administered. The format, level, and administration of Test 1, 2, and 3 were comparable; the syntactic structures in each of the test items were identical, but the nouns and verbs were different. The internal consistency of the three tests were assessed using Cronbach's Alpha. The reliability coefficients were uniformly satisfactory for both parts of the tests: for Part I they were .76, .77, and .79; for Part II they were .73, .77, and .78.

Correlations between Parts I and II of each of the three test forms seem to indicate that, as expected, they test highly related, but not identical skills ($p<.05$). The parallelism of the different forms of the test being used is shown by the high correlations between them: for Part I the r's ranged from .54 to .59, and for Part II from .63 to .72. Further test development, including item analyses, is still necessary to improve the usefulness of these tests.

A record keeping module was integrated in the *Yes-No Game* to facilitate data collection, and to provide easy access to information of the students' performance while they interacted with the program. Continually updated "Records" of correct and incorrect responses enabled the research observers to check the subjects' progress during the intervention. Detailed "Histories" of every keystroke and response in the syntactic practice, as well as the time between each response, were designed to be converted to text files for later analysis of the pattern of the subjects' sequential responses.

Results

<u>Part I - The Multiple Choice Section</u>. As displayed in Figures 5.2 and 5.3, both phases of the intervention are associated with pre- post-test gains. As determined by Analysis of Variance (ANOVA) and paired contrasts using a "Least Significant Difference Test (LSD)," significant gains in syntax knowledge were made by each group receiving the CAI-Syntax treatment: the means for Group A rose from 63.53 in Test 1 to 74.35 in Test 2 ($p<.06$), and the means for Group B rose from 70.80 in Test 2 to 87.73 in Test 3 ($p<.05$). In comparison, the control group (B) demonstrated no significant gains with the alternate CAI from Test 1 to 2. Even when Group A was tested two weeks after the CAI-Syntax treatment, their Test 3 scores did not fall below the level of Test 2, suggesting that the improvements in syntactic knowledge were retained.

Although we presumed that we had matched pairs, in both the *Yes-No I* and *II* studies, Group B performed better than Group A in Parts I and II of all tests for both studies; however, the

differences were not statistically significant. After the studies were completed, the results from the students' new SAT-HI were released; they indicated that at the time of the experiments the students were no longer exactly matched on reading scores. With such a small sample, significant differences in only a few of the students' reading scores are sufficient to explain the better performance of Group B. Because in English language studies with this population there is a potential confounding effect of students' reading abilities, we decided to repeat the analyses in the previous section, but include an assessment of the interaction of reading ability with the intervention (i.e., students with high reading ability would benefit more from the CAI Syntax treatment than students with lower reading scores). The procedure we employed was Analysis of Covariance (ANCOVA). Results indicate no independent interaction effects for Part I. This finding is not surprising considering the nature of this part of the test, which requires only recognition of grammatical correctness, not reading comprehension of paragraph stimuli as in Part II.

Part II - The Language Production Section. Whereas Part I involves recognition of grammatical correctness, primarily in syntax, Part II is dependent upon the comprehension of the 10 stimulus paragraphs, i.e. the multiple tasks involved in reading, such as making inferences from context clues. To investigate the effects of CAI-Syntax intervention on language production , we again used ANOVA and LSD procedures to compare group means. Although there is an increase in test scores for both groups (with Group A improving from a mean of 44.12 to 51.77, and Group B improving from 57.00 to 61.00) after the intervention, the gains are not statistically significant.

As in the analyses for Part I, we used ANCOVA to test for the effects of an interaction between the intervention and the reading scores. For both Groups A and B there was a significant interaction which was independent of any main effect of the intervention (for Group A, $F=5.04$, $p<.01$; for Group B, $F=7.59$, $p<.001$) indicating that students with high reading ability benefit more from the CAI-Syntax treatment, as measured by a test requiring comprehension skills, than do students with lower reading ability.

In order to supplement the results obtained by the statistical analyses of the pre- and post-test scores, an error analysis of the sentences actually produced by the students in Part II of the test was undertaken. The analysis classified all of the mistakes found in the tests into 25 error categories. In addition to the total number of errors found in the total corpus formed by the pre- and post-test responses, Table 1 also reports pre- and post-test results for selected error categories which seemed particularly related to the grammatical procedures taught by the treatment. These categories — some derived from collapsing some of the 25 catgeories originally used in the analysis — are as follows:

Table 1. ***Yes-No II*** **— Summary of Error Analysis**

	GROUP A			GROUP B		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Total number of errors	236	194	198	196	154	165
Selected Error Types						
A	13	15	19	13	6	12
B	54	30	35	37	33	28
C	18	13	22	13	13	12
D	20	15	9	15	24	13
E	11	13	4	13	10	7
F	18	22	15	12	9	14

A. Substitution of a possible pattern for the one expected by the test stimulus (e.g., "How do you feel?" instead of "Were you sick?") This response is not really an error but constitutes a failure of the test to evoke the desired pattern.

B. Confusion of second and third person in the subject to be addressed.

C. Use of a pattern or a total sentence which is semantically impossible in response to the stimulus.

D. A word omitted from what appears otherwise to be a correct response.

E. A word added to an otherwise correct response.

F. The pattern used is incorrect because of confusion in word order.

The error analysis also revealed other frequent errors which are often mentioned in the literature dealing with English produced by the Deaf (e.g., omission of the article, and dropping of verbal and noun morphemes like final "s"). However, further analysis of these errors did not seem germane or relevant to purposes of the intervention and of this report.

Statistical interpretation of the data of Table 1 must be undertaken with some caution, primarily because the error analysis shows only type and frequency of errors in pre- and post-test but not the opportunity to commit them. Opportunities were at best only roughly equivalent between pre- and post-test, primarily because omission of opportunity by totally omitting responses is not taken into account in the error counts, and because students could create their own

opportunities for errors by responding in unexpected patterns. Still, the pre- post-test comparison scores indicate improvement as a result of the intervention. In some categories (like "A"), the decrease in errors may simply be due to the students' recognizing the intention of the treatment and/or the test maker. A gain (i.e., decrease in error) in the other categories (especially "F") seems strongly associated with the success of the intervention. In the case of one error (B) there seems to be an increase from pre- to post-test, namely in the confusion of second and third person (especially the substitution of the third person for the second). This semantic error, which was not specifically dealt with in the treatment, is among the most frequently found in the corpus of pre- and post-test responses and should become the object of further study and planned intervention.

As summarized in Table 1, the frequent mistakes known to relate to specific problems of the Deaf, but not to the experiment under consideration, are omitted in the presentation and appear only in the reported table.

The overall patterning of errors points to the following:

1. The control group (B) seems somewhat stronger than the experimental group throughout all three tests.

2. An overall decrease of errors takes place going from Test 1 to Test 2. The results seem approximately the same for the experiment and control groups, and perhaps is due to familiarity with the type of test being used.

3. The results of the third test administration are not very different from those of the second. Neither retaking of the test (Group A) nor treatment (Group B) change the overall incidence of errors.

The distribution of errors in specific categories does not show a consistent decrease as the result of the preceding treatment. (E.g., a possible treatment effect in error category B in Group A — a drop from 54 in Test 1 to 38 in Test 2 — is not matched by a similar drop in Group B, where the decrease in errors is only from 33 to 28.) It can be noted again that word order confusion — the problem most directly addressed by the treatment — is a less frequent error than the confusion in the person to be used as the intended addressee of the question.

Summary

The data shown in Figure 5 clearly demonstrated the effectiveness of the intervention. Significant gains in syntax knowledge, as measured by Part I of the tests, were made by each

group receiving the CAI-Syntax intervention. In contrast, the control group made no significant gains in each phase. While the means for Group A rose from 63.53 to 74.35 ($p < 0.06$) after the intervention, Group B demonstrated no significant gains with the alternate CAI. After the intervention, however, the means for Group B rose from 70.80 to 87.73 ($p<0.05$). Interestingly, when Group A was tested two weeks after the CAI-Syntax treatment, they retained the syntax knowledge they had acquired earlier. In our experience, these findings are impressive considering the brief duration of the treatments (90 to 135 minutes) and the persistence of these skill deficiencies prior to the treatment.

Two aspects work against the intervention having a pronounced affect on students' syntactic ability, as measured by the open-ended Part II test: (1) The material in Part II is much more difficult than the material in Part I, and (2) deaf students require years of schooling to use the auxiliaries, DOES, DO, and DID (Quigley, 1978) in the test situation and often never reach the point of employing them correctly in spontaneous language production. Under these circumstances, even the marginal gains evidenced after the treatment are encouraging.

Conclusions: Educational Importance

Effecting a change in language behavior that has become ingrained is a difficult, complex, and time-consuming task. As evidenced by the significant results of the intervention, however, it appears that our CAI approach has substantial potential for accelerating the acquisition of English syntactical knowledge by the Deaf. The fact that such meaningful improvement could be obtained in an area where failure is the norm should not be overlooked, especially for an intervention of only two to three class periods.

Although the instructional intervention focused on yes-no question formation, the results of the experiment suggest the desirability of building a complete CAI syntax curriculum based on visualization techniques as linguistic bridges from ASL to English syntactic structures. Visualization and simultaneity of expression in well-designed CAI may be particularly important to the basic concepts in education of the Deaf; these aspects can build on certain strengths of the Deaf that are not utilized in standard teaching materials — those that are visual and spatial like ASL, rather than linear and sequential like English.

As a result, the difficulty of making grammatically correct judgements (as evaluated on Part I of the tests we administered), and the distinctive, ungrammatical deaf syntactic structures that have persisted in spite of years of schooling (as studied in Part II), may be ameliorated. Programs such as the *Yes-No Game* may enable deaf students to proceed through three phases of language learning with more facility: (1) recognition of grammaticality, (2) understanding of rules used in sentence production, and (3) actual production of grammatical sentences for real communication. The results of the *Yes-No Game* indicate a potential breakthrough in the heretofore intractable problems deaf students encounter in attempting to master English syntactic structures.

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